MADROÑO, Vol. 51, No. 4, pp. 372–378, 2004

VTM PLOTS AS EVIDENCE OF HISTORICAL CHANGE: GOLDMINE OR LANDMINE?

JON E. KEELEY
U.S. Geological Survey, Western Ecological Research Center, Sequoia National
Park, Three Rivers Canyon National Park, Three Rivers, CA 93271
jon_Keeley@usgs.gov
and
Department of Ecology and Evolutionary Biology
University of California, Los Angeles, CA 90095

ABSTRACT

VTM (Vegetation Type Map) plots comprise a huge data set on vegetation composition for many parts of California collected mostly between 1929 and 1935. Historical changes in vegetation have been inferred by sampling these areas many decades later and evaluating the changes in plant dominance. VTM plots can not be precisely relocated, and it has been assumed that errors resulting from this problem are inconsequential or can be eliminated by comparison with a composite of multiple contemporary plots. This study examines that assumption for southern California shrubland landscapes by comparing the differences in species composition between closely positioned VTM-sized plots. Comparing shrub species density in 400-m^2 plots separated by 30 m (center to center), I found that all species exhibited considerable differences in density even over this short distance. This patchiness in shrub distribution could lead to major errors in historical reconstructions from VTM plot data. Two methods are proposed for dealing with this problem. One is to collect multiple samples from the vicinity of the VTM plot and use the observed spatial variation to set bounds on the temporal changes required to represent significant historical change. The other is to look at broad landscape changes reflected in the averages observed in a large sampling of sites.

Key Words: chaparral, maps, photographs, plots, sage scrub, sampling.

Reconstructing historical changes in landscapes is becoming increasingly important as a means of understanding future climate change impacts. Techniques such as dendrochronology have been successfully applied to reconstructions of fire history and climate influences on tree growth but are of limited value outside of forests (Swetnam 1993; Skinner 1997). Phytoliths have proven success in recognizing changes in a variety of herbaceous and woody vegetation types (Bartolome et al. 1986; Delhon et al. 2003). Historical photographs have value in detecting broad landscape changes, but it is difficult to quantify the changes in vegetation composition (Gibbens and Heady 1964). Older sample plots are an increasingly valuable resource (Stephens and Elliott-Fisk 1998), and one database with great potential is the quantitative sample plots recorded by the Vegetation Type Map (VTM) project in California initiated in the early part of the 20th century (Wieslander 1935a).

The VTM project, under the direction of A. E. Wieslander mapped over 15 million hectares, or approximately 40 percent of the vegetation in California between 1929 and 1935 (Critchfield 1971). VTM maps were accompanied by quantitative sampling of more than 18,000 plots of 400-m^2 (800 m^2 in forests), field notes, and landscape photographs (Wieslander et al. 1933). These maps and associated data laid the foundation for our current understanding of plant community distribution in California (Colwell 1977). Plot data, however, have perhaps received the most use and have contributed significantly to longstanding efforts at plant community classification within the state (Jensen 1947; Griffin and Critchfield 1972; Allen et al. 1991; Allen-Diaz and Holzman 1991) and to validate models of plant distribution (Vayssieres et al. 2000; Franklin 2002).

Studies using VTM data for classification have implicitly or even explicitly assumed that there has been no significant change in vegetation over this time that would affect classification schemes. However, increasingly these VTM plot data are more important as historical records, and in recent decades all three of the VTM data types, maps, photographs and plot samples, have been utilized to reconstruct vegetation change.

Apparently the first use of these data for historical study was a comparison of both VTM plot data and accompanying photographic record with 1972 patterns in northeastern San Diego County (Bradbury 1974). The general conclusion from this study was that there had been relatively little change over this 41 year period, illustrated by a distinct landscape mosaic of chaparral and sage scrub along the Banner Grade Road in eastern San Diego County (Bradbury 1978).

Dodge (1975) also used VTM photographs to study historical changes in San Diego County vegetation. However, he found that most photographs were close ups of vegetation types, and it was not possible to relocate the exact location for most of the ones he used in his study. He compared vegetation changes evident from re-photographing the same general area and concluded that 40 years of fire suppression had caused profound changes in vegetation. Taylor (2000) likewise presented pairs of VTM photographs and "retakes." He used written reference points to more precisely relocate sites (Alan Taylor, 9 July 2003 e-mail), and the similar tree spacing evident in the photos further suggests the paired photos were from the same site. Three of the four sites he presented were interpreted as providing evidence that decades of fire suppression contributed to increased forest density.

The original Wieslander maps also have been used to document historical changes. Freudenberger et al. (1987) quantified the grassland patterns recorded by the VTM maps and compared them with more recent vegetation maps for portions of Los Angeles and Ventura counties. Contrary to Bradbury's (1978) demonstration of stability in landscape patterns, they found very marked shifts in the distribution of grasslands and coastal sage scrub, which were tied to disturbance patterns.

While all three types of VTM data have been used for historical reconstructions, the plot data have received the greatest attention for reconstructions of vegetation change. These studies have been done in southern California shrublands (Bradbury 1974; Minnich and Dezzani 1998), central California oak woodlands (Holzman and Allen-Diaz 1991; Holzman 1993), and coniferous forests in the San Bernardino Mountains of southern California (Minnich 1978; Minnich et al. 1995) and the Sierra Nevada (Bouldin 1999). By contrasting contemporary plot samples with the VTM plot data, many of these studies have reported substantial changes in vegetation type and community composition. However, the precise location of VTM plots was never recorded so that it is not possible to actually "*resample*" the original 400 or 800 m^2 plots but only sample plots in the approximate vicinity of the original plots. Historical reconstructions from most of all of these studies presume that differences between the original VTM plot species composition and contemporary samples reflect temporal changes in these landscapes, but failure to adequately evaluate small scale spatial variation may lead to spurious conclusions about historical changes.

Since VTM plots cannot be precisely relocated and re-sampled, it is important to examine the scale of spatial variation on these landscapes. None of the VTM plot studies have evaluated the extent of spatial variation in the context of the estimated proximity of original and contemporary plots. A misplaced contemporary plot, or even a composite of plots, could be a poor baseline for examining historical changes with VTM data. The purpose of the present study was to evaluate assumptions behind studies that rely upon VTM plots as a baseline for historical changes, and to evaluate limitations in the use of such data. Specifically, most VTM studies have implicitly assumed that imprecise alignment of plots does not interfere with conclusions about historical change. This study evaluates the extent of spatial variation in VTM-size plots that are separated by only 10 m in coastal sage scrub and chaparral communities in southern California. While these data do not specifically address the accuracy of VTM plot reconstructions for forest or woodland vegetation, they do reflect on assumptions used in those studies.

VTM Plot History and Reconstructions

One of the important drivers of the Vegetation Type Map project was concern with fire hazard in southern California chaparral (Colwell 1977), and thus this region had the most extensive and detailed coverage (Critchfield 1972). Sample plots were chosen to provide a fairly even geographic distribution of each vegetation type (outside of desert and alpine habitats) and age class. The sample protocol was designed to collect information for many purposes, including "unforeseen developments of the future" (Wieslander 1935b). The sample plots were rectangular ~400-m^2 plots (0.1 acre) or ~800-m^2 in forests with a length:width ratio of 4 (2 in forests) oriented perpendicular to the contour (Wieslander et al. 1933). Plots were laid out parallel to the ground surface and thus not slope-corrected, although this would not have made any detectable difference since plot boundaries were only visually estimated from a line running down the center of the plot.

Crews sampled non-forested plots by subdividing them into 100 equal size ~milacre squares, ~4 m^2 each. Only the dominant species in each square was recorded and it was assumed to fill the entire plot, thus representing 1% of the total plot cover. Where total cover was less than 50% the square was classified as bare ground. Data were expressed as frequency of squares dominated by each species. This metric represented relative cover and not ground surface cover, e.g., 100% cover only means shrub cover in each square was >50% and thus the plot could have had substantial bare ground. Because subordinate plants were not recorded from the squares, this methodology is inappropriate for estimates of density, and is of limited value for separating subsequent growth of subordinates from colonization and recruitment of new individuals. Height was also recorded and dead individuals indicated as such and squares lacking a dominant shrub or tree were recorded as bare ground, annual plants, cactus or *Pteridium*. A list of additional woody species was also recorded for each plot. In forest and woodland plots actual tree density was recorded for those individuals with a dbh over 10 cm, tallied in classes of ~10–30, 30–60, 60–90, and >90 cm, which were estimated, not measured (Bouldin 1999).

Plot locations were crudely indicated on a 1: 62,500 topographic map by a hand-drawn circle with a radius ranging from approximately 110 m (Robert S. Taylor, Santa Monica Mountains National Recreation Area, 23 May 2003 email) to 300 m (Franklin 2002), describing an area of roughly 3.8 to 28 ha, respectively. In addition, the 19th century maps that were used were not accurate topographic maps that had been planimetrically surveyed, and thus contained substantial random and systematic errors (Bouldin 1999). Field notes included information on slope exposure (N, NW, W etc) and slope inclination, but these were based on visual estimates (according to former crew member Daniel Axelrod, personal communication cited in Bouldin 1999). Also of value in locating plots were notes on roads, rivers, prominent trees, and other prominent features, and this would contribute to more precise relocations in woodlands with older "landmark" trees. In addition to locational data, assessments were made of vegetation penetrability (i.e., ease of entering brush vegetation), parent rock material, evidence of erosion, and any special fire hazards due to snags. Countless other types of natural history data were collected, and voucher specimens added new species to our flora (e.g., Wieslander and Schreiber 1939).

Studies of historical changes in vegetation by "re-sampling" VTM plots have treated the problem of relocating the original plots differently. The only apparent criterion of Bradbury (1974, p. 29) was that the plots be relocated to "my satisfaction." On the other hand, Minnich (1978, p. 156) stated, "Unfortunately, they could not be precisely relocated from the mapped locations given on the VTM topographic sheets," and consequently, he used these data only as a means of providing the context for interpreting historical aerial photographs of coniferous forests.

In contrast, studies in central California oak woodlands by Allen-Diaz and Holzman (1991) and Holzman (1993) reported that by utilizing data taken by the VTM crews on elevation, slope aspect, and inclination, they could narrow the location of the re-sampling plot to within 5 m of the original plot center most of the time, and never more than 50 m. However, no information was presented on the types of evidence used to draw conclusions about this level of precision in relocating VTM plots. It was implicitly assumed in these studies that the level of spatial variation on these sites was insufficient to introduce significant error due to misplacement of the contemporary plots, but no supporting evidence was presented to substantiate this assumption.

Minnich et al. (1995) studied coniferous forests and reported with confidence that they could relocate, within 100 m, the original VTM plots, however, no details were given on how one might repeat this level of precision in relocating plots. They utilized field notes on distance to roads and prominent trees, but did not explain how the figure of 100 m was derived or present evidence that this was based on anything more than "expert opinion." However, these investigators did acknowledge the likelihood that variation resulting from not placing the contemporary sample in precise alignment with the VTM sample could lead to erroneous conclusions about temporal variation. Their solution was to sample three plots within 0.5 ha of the presumed site of the VTM plot. They subjectively placed these three plots but gave no criteria for choosing the sample locations. This subjective placement of plots represents a major interpretation problem since their clearly articulated goal was to demonstrate historical changes due to fire suppression. These three plots were combined and averaged to produce a composite contemporary sample that could be compared with the historical data. This approach implicitly assumes that the mean of the current spatial variation in forest composition would produce a better basis for comparison with historical VTM plots than some other measure such as the variance in contemporary forest structure.

Minnich and Dezzani (1998) extended the use of VTM plots in an investigation of historical changes in the composition of sage scrub communities of western Riverside County. Despite the fact that they studied a very different community, and were attempting to relocate plots only half the size of those used in Minnich et al. (1995), they too reported they were able to relocate the original plots to within 100 m, but provided no protocol for repeating this level of precision. These authors also explicitly recognized that some change observed between the VTM plots and the contemporary samples could "be due to sampling error in relocation." To correct for this source of error, they sampled three plots subjectively scattered over an area of 1 ha; however, they did not explain why the sample area for this study was doubled over the 0.5 ha used in Minnich et al. (1995).

A different approach was followed in the extensive study of historical changes in northern Sierra Nevada conifer forests by Bouldin (1999). He acknowledged at the outset the inherent problems of precisely relocating VTM plots—"it proved infeasible in the Sierra Nevada because of the lack of on-the-ground markers and inaccuracies in original mapped plot locations." Consequently, Bouldin made no claims of being able to relocate VTM plots, rather he averaged the results from 2442 VTM plots sampled in 1935 and compared the patterns with 6221 contemporary USFS Forest Inventory and Analysis (FIA) plots distributed across the same region and sampled in 1992.

METHODS

To examine levels of spatial variation in southern California shrublands, I utilized data from an earlier study that included 90 sites of sage scrub or chap-

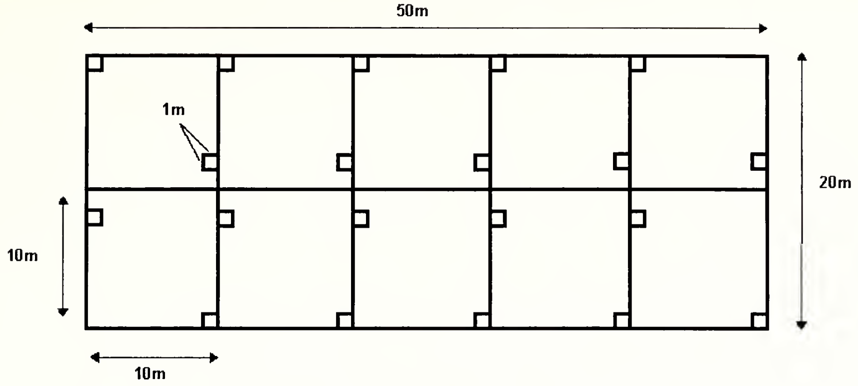

FIG. 1. Tenth-ha nested sampling method used in Keeley (1998) and Keeley and Fotheringham (2003). Plot is laid out with the long axis parallel to the contour. For this comparison the total density of shrubs in the two upper and two lower contiguous 100-m^2 subplots at the left end comprised a 400-m^2 plot and this was compared with a similar matching plot from the other end. Outer boundaries were separated by 10 m and by 30 m center to center. The 1-m^2 nested quadrats were not sampled for this study.

arral distributed over several counties (Keeley 1998; Keeley and Fotheringham 2003). Although these sites had burned prior to study, data utilized here comprised prefire shrub density estimates. Sampling used 1000 m^2 rectangular (20 × 50 m) sites subdivided into ten 100 m^2 subplots (Fig. 1). Within each site, two VTM size 400-m^2 plots could be assembled by combining four subplots at one end of the site and four at the opposite end. Thus, we have samples of prefire shrub density in matched VTM-size plots separated by 10 m. Since studies that have used VTM plots for historical reconstructions have stated that their re-samples were within 100 m of the original plot, our analysis of differences 30 m apart (center to center) should provide a lower limit of similarity to be expected in VTM studies in these vegetation types.

These plots were not identical to VTM plots because they were square and not rectangular, however, in these vegetation types, plot shape at this scale has no significant effect on species richness, cover, or density (Keeley and Fotheringham, in review). Another difference between the VTM sampling and this study is the metric used for comparison. Absolute shrub density is used here, rather than the relative measure of dominance used in the VTM sampling, a metric not clearly equated with either absolute cover or density. However, there is no reason to believe that the magnitude of spatial variation should be different between these two metrics. This conclusion is based on the fact that, regardless of density, the VTM plots only recorded a single individual from each milacre square, and in this study the mean density recorded for each species was less than one plant per milacre.

In this analysis the number of shrubs of each species were tallied for the 400-m^2 plot at one end of each of the 90 tenth-ha sites and compared with the number recorded from the plot at the other end of the site. For each species at each site, the difference in density between the two matched samples was expressed as a percentage of the mean calculated for the two samples.

RESULTS

Table 1 shows a comparison of shrub density for 18 species in matched 400-m^2 plots separated by 10 m (30 m center to center). Only species reported from more than a dozen sites were included in this table, and the focus was on the differences observed between these two "matched" plots. The smallest average difference observed was 67% for *Ceanothus megacarpus,* and most species exhibited >100% difference between plots.

In terms of absolute density, the difference between matched plots typically was on the order of 20–40 individuals, but for half of the species there was at least one site where the difference was hundreds of individuals (Table 1).

For nearly every species, these differences diminished greatly when all sites were combined; in other words when the left-side plots from all sites were summed, and that total compared with the total from all right-side matched plots, the differences were lower (Table 1). Thus, the differences between matched plots "averaged out" over large samples. This was affected by the number of sites a species occurred at, as illustrated in the negative relationship between sample size and difference calculated on the totals from all sites (Fig. 2).

DISCUSSSION

The spatial variation observed in southern California shrublands suggests that species are clumped at a scale of 400-m^2 or less. As a consequence there is potentially a very significant error introduced if VTM plots are not precisely relocated or at least closer than the 10 m that separated paired plots in this study. Minnich et al. (1995) have made a valu-

TABLE 1. DIFFERENCE IN DENSITY BETWEEN MATCHED 400-m^2 PLOTS SEPARATED BY 10 m IN CHAPARRAL AND SAGE SCRUB VEGETATION, EXPRESSED AS 1) A PERCENTAGE OF THE MEAN BETWEEN THE MATCHED SAMPLES, 2) THE DIFFERENCE WHEN PLOTS FROM ALL SITES ARE FIRST COMBINED BEFORE CALCULATING THE DIFFERENCE, OR 3) THE ABSOLUTE DIFFERENCE IN DENSITY.

Species	Number of sites	Average difference between matched plots (% of mean) $\bar{x}$ + SE	Difference when all matched plots from one end of the plot are summed and compared with the sum of those from the other end (% of mean)	Absolute difference	
				Maximum	Mean of all sites
Adenostoma fasciculatum	44	78 + 10	12	141	34
Artemisia californica	47	74 + 10	13	75	15
Ceanothus crassifolius	12	112 + 24	16	94	18
Ceanothus megacarpus	14	67 + 16	25	403	59
Cercocarpus betuloides	13	195 + 4	115	114	20
Encelia californica	13	123 + 20	<1	283	82
Eriogonum fasciculatum	53	86 + 10	2	103	21
Hazardia squarrosus	33	125 + 13	8	476	41
Heteromeles arbutifolia	19	156 + 17	36	13	4
Malosma laurina	40	124 + 12	24	211	14
Mimulus aurantiacus	23	115 + 15	36	364	35
Quercus berberidifolia	20	105 + 18	3	32	5
Rhamnus crocea	52	137 + 10	8	56	4
Rhus integrifolia	20	100 + 15	35	74	14
Rhus ovata	15	145 + 17	51	5	2
Salvia apiana	18	104 + 14	7	86	19
Salvia mellifera	46	113 + 10	24	136	25
Yucca whipplei	29	120 + 13	5	29	7

able contribution by recognizing the potential for spatial variation confounding historical reconstructions when exact plot placement is impossible. Although the approach of sampling multiple plots and *averaging* those results to produce a composite contemporary sample may seem intuitive (Minnich et al. 1995; Minnich and Dezzani 1998), there is no clear theoretical basis for this approach. While we have not compared the pattern of variation with three samples, the data in Table 1 illustrates that if two sample plots (10 m apart) are combined and averaged, the difference between the average and any one of the two plots may be rather large. When vegetation is patchy as in the case of these shrublands, a composite could be more dissimilar from the original VTM plot than any one of the individual sample plots.

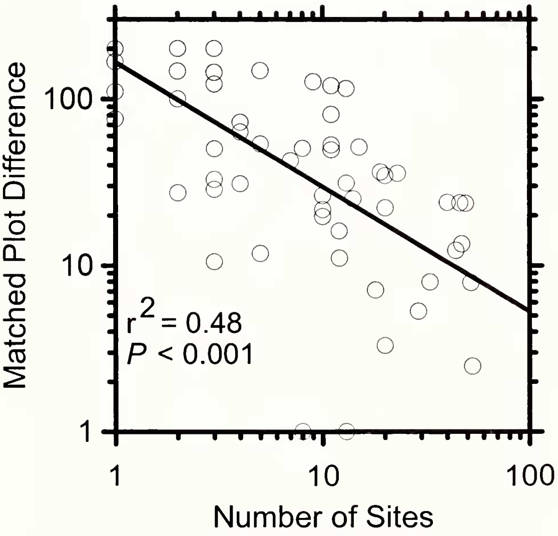

FIG. 2. Relationship between number of sites occupied by a species and the difference between left-side plots vs right-side matched plots when calculated from the totals across all sites (column 3 from Table 1, also includes less common species not listed in Table 1).

I suggest that a more justifiable use of multiple contemporary samples is to calculate the level of spatial variance observed between these plots and use this as a baseline for interpreting the extent of real historical change. In other words, if the observed spatial variation exceeds the difference between the VTM plot and the contemporary composite samples, then there would be little justification for concluding that one is observing historical changes. Other methods for sorting out spatial effects on estimates of temporal change have been proposed (Stewart-Oaten et al. 1995; Benedetti-Cecchi 2003).

Based on the results from the present study, it seems likely that considering only those comparisons where the contemporary spatial variance is less than the difference between VTM and contemporary plots will ultimately lead to the exclusion of a substantial number of VTM—contemporary plot comparisons. Thus, a preferable approach would be that pioneered by Bouldin (1999). He made no attempt to relocate VTM plots, rather he used the averages calculated from very large sample sizes and compared these with averages calculated on a large number of contemporary samples. Our data support that approach since differences between plots clearly even-out as sample size increases (Fig. 2). However, this is almost certainly a function of species density and similarity of sites under study, and these parameters would need to be determined for each study.

The results of the present study suggest that the broad generalizations about historical changes using VTM plots are likely valid; however, they raise serious questions about many of the very specific changes that are often based on single or just a few plots. For example, the reasonably large sample size (n = 78) of Minnich and Dezzani (1998) were likely sufficient to balance out any differences due to failing to precisely relocate contemporary sample plots. Thus, their generalization that sage scrub cover has declined during the 20th century is justifiable. However, many of the specific conclusions about changes in cover of particular species in Minnich (1978) and Minnich and Dezzani (1998) involved relatively small sample sizes, which are more likely affected by sampling error due to relocation problems. In addition, any species-specific comparisons of changes in cover are highly problematical because of the VTM protocol that only considers the cover of the dominant plant in each 4-m^2 square. It is easily possible for the cover of a species to remain the same from the time of the VTM survey to the present and yet be recorded as exhibiting dramatic declines in cover, if another species in many of the squares increased its cover during that period.

ACKNOWLEDGMENTS

I thank James Bartolome, C.J. Fotheringham, Max Moritz, Carl Skinner, Nathan Stephenson, and Robert Taylor for useful comments on an earlier draft.

LITERATURE CITED

ALLEN, B. H., B. A. HOLZMAN, AND R. R. EVETT. 1991. A classification system for California's hardwood rangelands. Hilgardia 59:1–45.

ALLEN-DIAZ, B. H. AND B. A. HOLZMAN. 1991. Blue oak communities in California. Madroño 38:80–95.

BARTOLOME, J. W., S. E. KLUKKERT, AND W. J. BARRY. 1986. Opal phytoliths as evidence for displacement of native Californian grassland. Madroño 33:217–222.

BENEDETTI-CECCHI, L. 2003. The importance of the variance around the mean effect size of ecological processes. Ecology 84:2335–2346.

BOULDIN, J. R. 1999. Twentieth-century changes in forests of the Sierra Nevada, California. Ph.D. dissertation. University of California, Davis, CA.

BRADBURY, D. E. 1974. Vegetation history of the Ramona Quadrangle San Diego County, California (1931–1972). Ph.D. dissertation. University of California, Los Angeles, CA.

———. 1978. The evolution and persistence of a local sage/chamise community pattern in southern California. Yearbook of the Association of Pacific Coast Geographers 40:39–56.

COLWELL, W. L., JR. 1977. The status of vegetation mapping in California today. Pp. 195–220 *in* M. G. Barbour and J. Major (eds.), Terrestrial vegetation of California. John Wiley & Sons, New York, NY.

CRITCHFIELD, W. B. 1971. Profiles of California vegetation. Research Paper PSW-76. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, CA.

DELHON, C., A. ALEXANDRE, J. F. BERGER, S. THIEBAULT, J. L. BROCHIER, AND J. D. MEUNIER. 2003. Phytolith assemblages as a promising tool for reconstructing Mediterranean Holocene vegetation. Quaternary Research 59:48–60.

DODGE, J. M. 1975. Vegetational changes associated with land use and fire history in San Diego County. Ph.D. dissertation. University of California, Riverside, CA.

FRANKLIN, J. 2002. Enhancing a regional vegetation map with predictive models of dominant plant species in chaparral. Journal of Vegetation Science 5:135–146.

FREUDENBERGER, D. O., B. E. FISH, AND J. E. KEELEY. 1987. Distribution and stability of grasslands in the Los Angeles Basin. Bulletin of the Southern California Academy of Sciences 86:13–26.

GIBBENS, R. P. AND H. F. HEADY. 1964. The influence of modern man on the vegetation of Yosemite Valley. Agricultural Experiment Station, Manual 36. University of California, Berkeley, CA.

GRIFFIN, J. R. AND W. B. CRITCHFIELD. 1972. The distribution of forest trees in California. Research Paper PSW-82. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, CA.

HOLZMAN, B. A. 1993. Vegetation change in California's blue oak (*Quercus douglasii*) woodlands, 1932–1992. Ph.D. dissertation. University of California, Berkeley, CA.

——— AND B. H. ALLEN-DIAZ. 1991. Vegetation change in blue oak woodlands in California. Pp. 189–193 *in* R. B. Standiford (ed.), Proceedings of the symposium on oak woodlands and hardwood rangeland management. USDA Forest Service, Pacific Southwest Research Station, Berkeley, CA.

JENSEN, H. A. 1947. A system for classifying vegetation in California. California Fish and Game 33:199–266.

KEELEY, J. E. 1998. Postfire ecosystem recovery and management: the October 1993 large fire episode in California. Pp. 69–90 *in* J. M. Moreno (ed.), Large forest fires. Backhuys Publishers, Leiden, The Netherlands.

——— AND C. J. FOTHERINGHAM. 2003. Species area relationships in mediterranean-climate plant communities. Journal of Biogeography 30:1629–1657.

——— AND C. J. FOTHERINGHAM, *in review*. Plot shape effects on plant species diversity measurements. Journal of Vegetation Science.

MINNICH, R. A. 1978. The geography of fire and conifer forests in the eastern Transverse Ranges, California. Ph.D. dissertation. University of California, Los Angeles, CA.

———, M. G. BARBOUR, J. H. BURK, AND R. F. FERNAU. 1995. Sixty years of change in Californian conifer forests of the San Bernardino Mountains. Conservation Biology 9:902–914.

——— AND R. J. DEZZANI. 1998. Historical decline of coastal sage scrub in the Riverside-Perris Plain, California. Western Birds 29:366–391.

Skinner, C. D. 1997. Toward an understanding of fire history information. Pp. 15–22 *in* S. Sommarstroms (ed.), Proceedings of the sixth biennial watershed management conference. Water Resources Center Report No. 92. University of California, Davis, CA.

Stephens, S. L. and D. L. Elliott-Fisk. 1998. *Sequoiadendron giganteum*-mixed conifer forest structure in 1900–1901 from the southern Sierra Nevada, CA. Madroño 45:221–230.

Stewart-Oaten, A., W. W. Murdoch, and S. J. Walde. 1995. Estimation of temporal variability in populations. American Naturalist 146:519–535.

Swetnam, T. W. 1993. Fire history and climate change in giant sequoia groves. Science 262:885–889.

Taylor, A. H. 2000. Fire regimes and forest changes in mid and upper montane forests of the southern Cascades, Lassen Volcanic National Park, California, U.S.A. Journal of Biogeography 27:87–104.

Vayssieres, M. P., R. E. Plant, and B. H. Allen-Diaz. 2000. Classification trees: an alternative non-parametric approach for predicting species distributions. Journal of Vegetation Science 11:679–694.

Wieslander, A. E. 1935a. A vegetation type map of California. Madroño 3:140–144.

———. 1935b. First steps of the forest survey in California. Journal of Forestry 33:877–884.

———, H. A. Jensen, and H. S. Yates. 1933. California vegetation type map: Instructions for the preparation of the vegetative type map of California. Unpublished USDA Forest Service report on file in library at Yosemite National Park, Yosemite Valley, CA.

——— and B. O. Schreiber. 1939. Notes on the genus *Arctostaphylos*. Madroño 5:42–43.